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High Temperature Oxidation Resistance of Welded Ferritic, Austenitic and Nickel Alloys for Balance of Plant (BOP) In Solid Oxide Fuel Cell (SOFC) Systems

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Outline

- Objective and Research Approach
- Materials
- GTAW Welding conditions
- Results and Analysis
- Conclusions

Objective

- Develop low cost 10 KW SOFC stationary power system.
  - Balance of plant Heat Exchangers (HE) cost reduction from $15,000 to $1,500.
    - Develop models to accurately predict the temperature in SOFC heat exchangers.
    - Select materials and manufacturing processes.
    - Use modeling to predict weld filler materials for the dissimilar metal joints.
    - Build and test heat exchangers to confirm model.

Research Approach

- Weld dissimilar metal materials without filler metal using GTAW.
- Heat the weld joints in air to 800ºC for 100 hr, 500 hr, 1,000 hr and 2,000hr.
- Determine cracking modes
- Hardness across the welds.
- Diffusion of alloy elements over time.
- Metallographic examination.

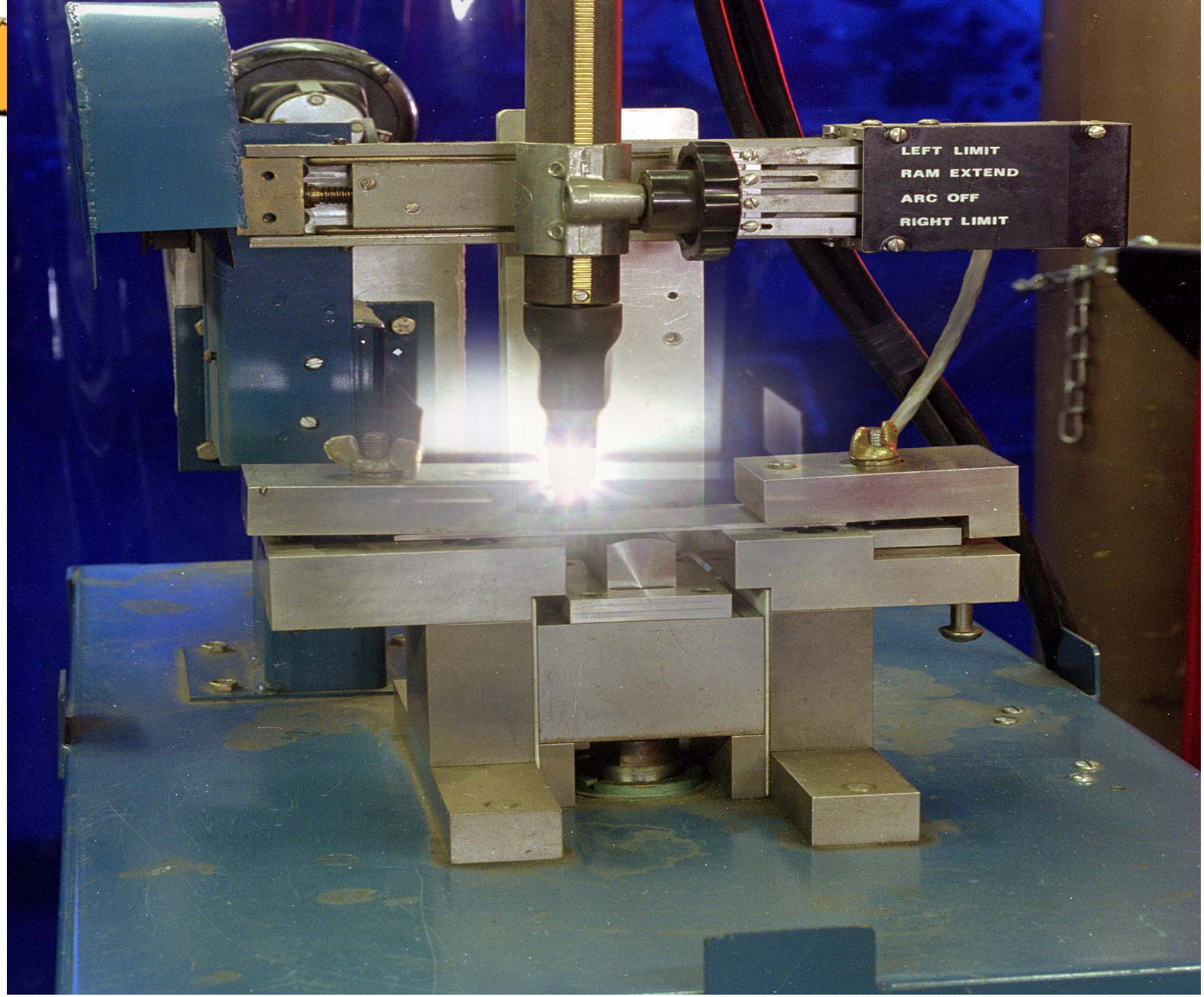
Materials used in the welding experiments

	Ni	Cr	Fe	C	Ti	Nb+Ta	Mo	Mn
IN 625	64	22	0	0.1	0.4	4	9	0.5
IN 600	75.4	15	7	0.1	0	2	0	0.5
409 SS	0	11	87.4	0.04	0.75	0	0	0.75
321 SS	11	18	68.5	0.08	0.4	0	0	2
347 SS	12	18	68.9	0.08	0	0.8	0	2

compositions in weight percent

Welding Conditions

- GTAW using a horizontal welding track.
- Samples 1in. x 6 in. x 1/4 in.
- Welded side by side.
- One welding pass on top and bottom.
- 13 volts and 132 amps.
- Welding speed 0.4 in per minute.


LEFT LIMIT
RAM EXTEND
ARC OFF
RIGHT LIMIT

Welding Results

- Solidification cracking and weld root cracking observed in all joints between all the stainless and the superalloys.
- Lack of full penetration was observed in all welds.
- No cracking was observed in the heat affected zone.

Weld Cracking

• 321 SS-INC625	centerline
• 321 SS-INC600	centerline
• INC625-409SS	centerline, crater
• 409 SS-INC600	centerline
• INC600-INC625	centerline, crater
• 321SS-409SS	no cracking
• 347SS-409SS	no cracking
• INC600-347SS	centerline, crater
• INC625-347SS	centerline, crater
• 321SS-347SS	no cracking

Chemical Analysis after 800ºC Heat Treatment

- SEM chemical analysis was used to determine the composition across the welded joints for Cr, Ni, Fe, and Mn.
- Changes in the composition across the welds were not observed with SEM as a function of time up to 2000 hours.

Hardness Results

	Hv	Hvσ
• 321 SS-INC625	171-226	24
• 321 SS-INC600	171-174	34.6
• INC625-409SS	226-169	20.4
• 409 SS-INC600	174-169	23.0
• INC600-INC625	174-226	40.2
• 321SS-409SS	171-169	14.6
• 347SS-409SS	163-169	17.0
• INC600-347SS	174-163	50.2
• INC625-347SS	226-163	55.0
• 321SS-347SS	171-163	17.0

Conclusions

- Autogenous GTAW welds in several stainless steels did not crack even after heat treatment at 800ºC for 2000 hours.
- Weld cracking was observed in all the joints with superalloys.
- Elemental diffusion was not observed in the welds in samples heated to 800ºC for 2000 hours.
- Vickers hardness measurements across the welds did not change in samples heated to 800ºC for 2000 hours.